

METHOD FOR CATALYZING OXIDATION/REDUCTION REACTIONS OF SIMPLE MOLECULES

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BACKGROUND OF THE INVENTION

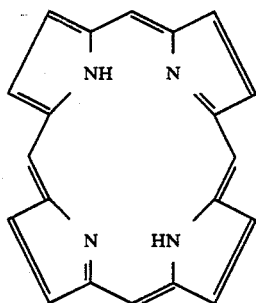
1. Field of the Invention

This invention relates to a method for catalyzing oxidation/reduction reactions based on polydentate nitrogen-containing chelating agents complexed with a metal atom.

(It must be noted that there is no universal agreement on the definition of "catalyst" or "catalyzing". Definition of the term "catalyst" varies depending on the art, for example, as between the fundamental investigator and the practitioner, and among researchers concerned with heterogeneous catalysis, homogeneous catalysis, polymerization reactions, and enzymes. In the present application a "catalyst" is defined as a substance that increases the rate of reaction and which may be regenerated or returned to its original state if it is transformed as the result of a catalytic reaction.)

2. Description of the Prior Art

The better known and studied catalytically active polydentate nitrogen-containing compounds are porphine-like molecules and their relatives (e.g., porphyrins). Porphine possesses a basic macrocyclic tetrapyrrole structure, illustrated below.



In many instances, porphine-based prosthetic groups are tightly or covalently bound to an apoenzyme, and complexed to an iron atom. In other instances Mg, Zn, Ni, Co, or Cu may be complexes to these porphines.

Proteins containing porphine-based prosthetic groups are known to perform diverse roles. They reversibly bind dioxygen for transport (hemoglobin and myoglobin), transfer electrons one at a time in membraneous respiratory chain (cytochromes), reduce peroxides (catalases and peroxidases), and act as terminal components in multi-enzyme systems involved in hydroxylation.

The catalytic functions of iron/porphine-proteins based on their metal centers are known. Two oxidation states of iron —Fe²⁺ and Fe³⁺—are known to be stable in aqueous solutions. These are the major redox forms of iron proteins.

The cytochromes are a group of iron-containing electron transferring proteins that act sequentially to transfer electrons from flavoproteins to oxygen. They all contain iron-porphine prosthetic groups. The cytochromes undergo reversible Fe²⁺—Fe³⁺ valence changes during their catalytic cycles. At least six types

of cytochromes have been identified : cytochromes b, b₅, c, c₁, a, and a₃. These cytochromes are primarily differentiated by their different reduction potentials.

The hydroperoxidases are ferri-(Fe³⁺)-hemoproteins which have as preferred substrates H₂O₂ (catalases) or alkyl peroxides (peroxidases). These enzymes act to oxidize phenols, aryl and alkyl amines, hydroquinones, ascorbate, cytochrome c, or glutathione.

In hemoglobins and myoglobins the iron atom does not undergo changes in valence as oxygen is bound or lost; it remains in the Fe²⁺ state. Both hemoglobin and myoglobin can be oxidized, however, to the Fe³⁺ forms, which are known as methemoglobin and metmyoglobin respectively.

Carbon monoxide combines with hemoglobin to form CO-hemoglobin. Each heme in hemoglobin can bind one carbon monoxide molecule but O₂ and CO cannot simultaneously bind to the same heme. The binding affinity for CO is about 200 times greater for carbon monoxide than for oxygen. Adventitious CO occupation of the heme position of a hemoglobin inactivates the heme.

It is known that when cytochrome c oxidase in the ferric, Fe³⁺, form is stored under an atmosphere of carbon monoxide, the heme iron of cytochrome a₃ will become reduced to Fe²⁺ and then bind CO. This reduction, accomplished under a CO atmosphere in the absence of other reactants, has been referred to as "autoreduction".

Young and Caughey (*Fed. Proc.*, 1980, 39, 2090(Abstract 2562)) have demonstrated that ¹³CO is oxidized to ¹³CO₂ by cytochrome c oxidase and O₂. This study also reveals that with ¹⁸O₂, ¹⁸O is incorporated into the CO₂ product. On this basis, Young and Caughey have suggested that the oxidation of CO to CO₂ occurs via the following reaction:



Thus, although no accepted mechanism explaining how "autoreduction" occurs exists, the heme mediated oxidation of CO has been proposed to proceed via one of the two following pathways:

(1) Young and Caughey have suggested that the reaction is a concerted process, occurring with dioxygen and two molecules of CO so that each O atom from the dioxygen molecule ends up in the CO₂ molecules produced.

(2) Bickar, Bonaventura and Bonaventura (Biophysical Society Annual Meeting, 1982, Feb. 14-17, Boston, MA) have suggested that the reaction is a two step process which consists of an initial reduction of cytochrome c oxidase by CO releasing CO₂, followed by the oxidation of cytochrome c oxidase by O₂.

SUMMARY OF THE INVENTION

In accordance with the present invention, it has now been discovered that catalyst systems based on one or more polydentate nitrogen-containing chelating agents (herein after simply referred to as chelating agent) complexed with a metal atom are useful for catalyzing the reactions



and

